

# Contents

Foreword .....	xxi
Preface .....	xxiii
Acknowledgments .....	xxix
About the Author .....	xxx
<b>Chapter 1 Introduction .....</b>	<b>1</b>
Evolution .....	2
The GNU Copyleft .....	3
Kernel.org .....	4
Mailing Lists and Forums .....	4
Linux Distributions .....	5
Looking at the Sources .....	6
Building the Kernel .....	10
Loadable Modules .....	12
Before Starting .....	14
<b>Chapter 2 A Peek Inside the Kernel .....</b>	<b>17</b>
Booting Up .....	18
Kernel Mode and User Mode .....	30
Process Context and Interrupt Context .....	30
Kernel Timers .....	31
HZ and Jiffies .....	31
Long Delays .....	33

Short Delays .....	36
Pentium Time Stamp Counter .....	36
Real Time Clock .....	37
Concurrency in the Kernel .....	39
Spinlocks and Mutexes .....	39
Atomic Operators .....	45
Reader-Writer Locks .....	46
Debugging .....	48
Process Filesystem .....	49
Allocating Memory .....	49
Looking at the Sources .....	52
<b>Chapter 3 Kernel Facilities .....</b>	<b>55</b>
Kernel Threads .....	56
Creating a Kernel Thread .....	56
Process States and Wait Queues .....	61
User Mode Helpers .....	63
Helper Interfaces .....	65
Linked Lists .....	65
Hash Lists .....	72
Work Queues .....	72
Notifier Chains .....	74
Completion Interface .....	78
Kthread Helpers .....	81
Error-Handling Aids .....	83
Looking at the Sources .....	85
<b>Chapter 4 Laying the Groundwork .....</b>	<b>89</b>
Introducing Devices and Drivers .....	90
Interrupt Handling .....	92
Interrupt Context .....	92
Assigning IRQs .....	94

---

Device Example: Roller Wheel .....	94
Softirqs and Tasklets .....	99
The Linux Device Model .....	103
Udev .....	103
Sysfs, Kobjects, and Device Classes .....	106
Hotplug and Coldplug .....	110
Microcode Download .....	111
Module Autoload .....	112
Memory Barriers .....	114
Power Management .....	114
Looking at the Sources .....	115
<b>Chapter 5 Character Drivers .....</b>	<b>119</b>
Char Driver Basics .....	120
Device Example: System CMOS .....	121
Driver Initialization .....	122
Open and Release .....	127
Exchanging Data .....	129
Seek .....	136
Control .....	137
Sensing Data Availability .....	139
Poll .....	139
Fasync .....	142
Talking to the Parallel Port .....	145
Device Example: Parallel Port LED Board .....	146
RTC Subsystem .....	156
Pseudo Char Drivers .....	157
Misc Drivers .....	160
Device Example: Watchdog Timer .....	160
Character Caveats .....	166
Looking at the Sources .....	167

<b>Chapter 6 Serial Drivers .....</b>	<b>171</b>
Layered Architecture .....	173
UART Drivers .....	176
Device Example: Cell Phone .....	178
RS-485 .....	191
TTY Drivers .....	192
Line Disciplines .....	194
Device Example: Touch Controller .....	195
Looking at the Sources .....	205
<b>Chapter 7 Input Drivers .....</b>	<b>207</b>
Input Event Drivers .....	210
The Evdev Interface .....	210
Input Device Drivers .....	216
Serio .....	217
Keyboards .....	217
Mice .....	220
Touch Controllers .....	227
Accelerometers .....	228
Output Events .....	228
Debugging .....	230
Looking at the Sources .....	231
<b>Chapter 8 The Inter-Integrated Circuit Protocol .....</b>	<b>233</b>
What's I <sup>2</sup> C/SMBus? .....	234
I <sup>2</sup> C Core .....	235
Bus Transactions .....	237
Device Example: EEPROM .....	238
Initializing .....	238
Probing the Device .....	241
Checking Adapter Capabilities .....	244

---

Accessing the Device .....	244
More Methods .....	246
Device Example: Real Time Clock .....	247
I2C-dev .....	251
Hardware Monitoring Using LM-Sensors .....	251
The Serial Peripheral Interface Bus .....	251
The 1-Wire Bus .....	254
Debugging .....	254
Looking at the Sources .....	255
<b>Chapter 9 PCMCIA and Compact Flash .....</b>	<b>257</b>
What's PCMCIA/CF? .....	258
Linux-PCMCIA Subsystem .....	260
Host Controller Drivers .....	262
PCMCIA Core .....	263
Driver Services .....	263
Client Drivers .....	264
Data Structures .....	264
Device Example: PCMCIA Card .....	267
Tying the Pieces Together .....	271
PCMCIA Storage .....	272
Serial PCMCIA .....	272
Debugging .....	273
Looking at the Sources .....	275
<b>Chapter 10 Peripheral Component Interconnect .....</b>	<b>277</b>
The PCI Family .....	278
Addressing and Identification .....	281
Accessing PCI Regions .....	285
Configuration Space .....	285
I/O and Memory .....	286
Direct Memory Access .....	288

Device Example: Ethernet-Modem Card .....	292
Initializing and Probing .....	293
Data Transfer .....	301
Debugging .....	308
Looking at the Sources .....	308
<b>Chapter 11 Universal Serial Bus .....</b>	<b>311</b>
USB Architecture .....	312
Bus Speeds .....	314
Host Controllers .....	315
Transfer Types .....	315
Addressing .....	316
Linux-USB Subsystem .....	317
Driver Data Structures .....	317
The usb_device Structure .....	318
USB Request Blocks .....	319
Pipes .....	321
Descriptor Structures .....	322
Enumeration .....	324
Device Example: Telemetry Card .....	324
Initializing and Probing .....	325
Accessing Registers .....	332
Data Transfer .....	335
Class Drivers .....	338
Mass Storage .....	339
USB-Serial .....	345
Human Interface Devices .....	348
Bluetooth .....	348
Gadget Drivers .....	348
Debugging .....	349
Looking at the Sources .....	351

---

<b>Chapter 12 Video Drivers .....</b>	<b>355</b>
Display Architecture .....	356
Linux-Video Subsystem .....	359
Display Parameters .....	361
The Frame Buffer API .....	362
Frame Buffer Drivers .....	365
Device Example: Navigation System .....	365
Console Drivers .....	380
Device Example: Cell Phone Revisited .....	382
Boot Logo .....	387
Debugging .....	387
Looking at the Sources .....	388
<b>Chapter 13 Audio Drivers .....</b>	<b>391</b>
Audio Architecture .....	392
Linux-Sound Subsystem .....	394
Device Example: MP3 Player .....	396
Driver Methods and Structures .....	399
ALSA Programming .....	409
Debugging .....	412
Looking at the Sources .....	412
<b>Chapter 14 Block Drivers .....</b>	<b>415</b>
Storage Technologies .....	416
Linux Block I/O Layer .....	421
I/O Schedulers .....	422
Block Driver Data Structures and Methods .....	423
Device Example: Simple Storage Controller .....	426
Initialization .....	427
Block Device Operations .....	430
Disk Access .....	432

Advanced Topics .....	434
Debugging .....	436
Looking at the Sources .....	437
<b>Chapter 15 Network Interface Cards .....</b>	<b>439</b>
Driver Data Structures .....	440
Socket Buffers .....	441
The Net Device Interface .....	443
Activation .....	444
Data Transfer .....	444
Watchdog .....	445
Statistics .....	445
Configuration .....	446
Bus Specific .....	448
Talking with Protocol Layers .....	448
Receive Path .....	448
Transmit Path .....	449
Flow Control .....	449
Buffer Management and Concurrency Control .....	450
Device Example: Ethernet NIC .....	451
ISA Network Drivers .....	457
Asynchronous Transfer Mode .....	458
Network Throughput .....	459
Driver Performance .....	459
Protocol Performance .....	461
Looking at the Sources .....	461
<b>Chapter 16 Linux Without Wires .....</b>	<b>465</b>
Bluetooth .....	467
BlueZ .....	469
Device Example: CF Card .....	471

---

Device Example: USB Adapter .....	471
RFCOMM .....	473
Networking .....	475
Human Interface Devices .....	477
Audio .....	477
Debugging .....	478
Looking at the Sources .....	478
Infrared .....	478
Linux-IrDA .....	480
Device Example: Super I/O Chip .....	482
Device Example: IR Dongle .....	483
IrComm .....	486
Networking .....	486
IrDA Sockets .....	487
Linux Infrared Remote Control .....	488
Looking at the Sources .....	489
WiFi .....	489
Configuration .....	490
Device Drivers .....	494
Looking at the Sources .....	496
Cellular Networking .....	496
GPRS .....	496
CDMA .....	498
Current Trends .....	500
<b>Chapter 17 Memory Technology Devices .....</b>	<b>503</b>
What's Flash Memory? .....	504
Linux-MTD Subsystem .....	505
Map Drivers .....	506
Device Example: Handheld .....	506
NOR Chip Drivers .....	511

NAND Chip Drivers .....	513
User Modules .....	516
Block Device Emulation .....	516
Char Device Emulation .....	517
JFFS2 .....	517
YAFFS2 .....	518
MTD-Utills .....	518
Configuring MTD .....	519
eXecute In Place .....	520
The Firmware Hub .....	520
Debugging .....	524
Looking at the Sources .....	524
<b>Chapter 18 Embedding Linux .....</b>	<b>527</b>
Challenges .....	528
Component Selection .....	530
Tool Chains .....	531
Embedded Bootloaders .....	531
Memory Layout .....	535
Kernel Porting .....	537
Embedded Drivers .....	538
Flash Memory .....	538
UART .....	539
Buttons and Wheels .....	539
PCMCIA/CF .....	540
SD/MMC .....	540
USB .....	540
RTC .....	541
Audio .....	541
Touch Screen .....	541

---

Video .....	541
CPLD/FPGA .....	542
Connectivity .....	542
Domain-Specific Electronics .....	542
More Drivers .....	543
The Root Filesystem .....	544
NFS-Mounted Root .....	544
Compact Middleware .....	546
Test Infrastructure .....	548
Debugging .....	548
Board Rework .....	549
Debuggers .....	550
<b>Chapter 19 Drivers in User Space .....</b>	<b>551</b>
Process Scheduling and Response Times .....	553
The Original Scheduler .....	553
The O(1) Scheduler .....	553
The CFS Scheduler .....	555
Response Times .....	555
Accessing I/O Regions .....	558
Accessing Memory Regions .....	562
User Mode SCSI .....	565
User Mode USB .....	567
User Mode I <sup>2</sup> C .....	571
UIO .....	573
Looking at the Sources .....	574
<b>Chapter 20 More Devices and Drivers .....</b>	<b>577</b>
ECC Reporting .....	578
Device Example: ECC-Aware Memory Controller .....	579
Frequency Scaling .....	583

Embedded Controllers .....	584
ACPI .....	585
ISA and MCA .....	587
FireWire .....	588
Intelligent Input/Output .....	589
Amateur Radio .....	590
Voice over IP .....	590
High-Speed Interconnects .....	591
InfiniBand .....	592
RapidIO .....	592
Fibre Channel .....	592
iSCSI .....	593
<b>Chapter 21 Debugging Device Drivers .....</b>	<b>595</b>
Kernel Debuggers .....	596
Entering a Debugger .....	597
Kernel Debugger (kdb) .....	598
Kernel GNU Debugger (kgdb) .....	600
GNU Debugger (gdb) .....	604
JTAG Debuggers .....	605
Downloads .....	609
Kernel Probes .....	609
Kprobes .....	609
Jprobes .....	614
Return Probes .....	617
Limitations .....	619
Looking at the Sources .....	620
Kexec and Kdump .....	620
Kexec .....	620
Kexec with Kdump .....	621

---

Kdump .....	622
Looking at the Sources .....	629
Profiling .....	629
Kernel Profiling with OProfile .....	629
Application Profiling with Gprof .....	633
Tracing .....	634
Linux Trace Toolkit .....	634
Linux Test Project .....	638
User Mode Linux .....	638
Diagnostic Tools .....	638
Kernel Hacking Config Options .....	639
Test Equipment .....	640
<b>Chapter 22 Maintenance and Delivery .....</b>	<b>641</b>
Coding Style .....	642
Change Markers .....	642
Version Control .....	643
Consistent Checksums .....	643
Build Scripts .....	645
Portable Code .....	647
<b>Chapter 23 Shutting Down .....</b>	<b>649</b>
Checklist .....	650
What Next? .....	651
<b>Appendix A Linux Assembly .....</b>	<b>653</b>
Debugging .....	659
<b>Appendix B Linux and the BIOS .....</b>	<b>661</b>
Real Mode Calls .....	662
Protected Mode Calls .....	665
BIOS and Legacy Drivers .....	666

<b>Appendix C Seq Files .....</b>	<b>669</b>
The Seq File Advantage .....	670
Updating the NVRAM Driver .....	677
Looking at the Sources .....	679
Index .....	681